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(54) PLASTICS SHEET MATERIALS

(71) We, BAKELITE XYLONITE LIMITED, a British Company, of 27 Blandford Street, London, W.1., do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to reflex light-reflecting materials.

The characteristic of such materials of returning a brilliant cone of light back towards the source thereof has made these materials increasingly popular for use in road safety applications and also in illuminated displays. Road signs, protective garments, pram covers and markers of this type have a greater visibility at night than do ordinary signs and markers because the amount of the reflected light which is dispersed outside of the field of view is extremely small, the reflected light being concentrated in a narrow beam which automatically returns towards the light source, for example the headlights of an approaching car.

Up to now reflex light-reflecting materials have been proposed consisting of glass beads or the like held in a binder material. Whilst, when new, these materials fulfil most of the requirements, they have the disadvantage of being susceptible to weathering. In particular, rain and contaminated mist may cause substantial deterioration in both the structural and optical properties of the material. In addition, these hitherto proposed materials have the disadvantage of being relatively inflexible and also their manufacture is expensive and, to some extent more complicated, than is desirable. Attempts to improve the weather resistance of these materials by the provision of a further outer layer of a plastics material have increased the expense of manufacture.

Because of these difficulties in manufacture, the materials hitherto proposed have been, in most cases, rather drab and unattractive in appearance in ordinary daylight, that is to say, no attempt has been made to utilize attractive patterns within the reflex light-reflecting materials, themselves. Thus, to date, garments made from these materials have, in general, been strictly uniform in appearance and have remained basically unattractive as regards the requirements of fashion.

According to one aspect of the present invention there is provided a plastics sheet material having preselected retro-reflective areas, which sheet comprises one or more layers of transparent or translucent plastics material, one layer, comprising the surface of said sheet, having one or more convex lens embossments on one surface thereof, said embossments having dimensions such that the plane or planes of reflective areas printed or coated on the other surface of the said one layer and/or on one or more surfaces of any further component layers of said sheet, which reflective areas together comprise at least 5%, generally from 5 to 95%, of the total area of said other surface, are so positioned relative to the focal region or regions of one or more of the lenses, that reflective areas together comprising at least 5% of said total area are in retro-reflective combination with one or more of said lenses, the other surface of said layer and the surfaces of any other component layers being substantially smooth and unembossed.

According to another aspect of the present invention there is provided a process for producing a plastics sheet material having preselected retro-reflective areas, which process

comprises forming a transparent or translucent layer of plastics material having one or more convex lens embossments on one surface of said layer, and printing or coating the other surface of said layer before, during or after said embossing, to provide reflective areas on said other surface which reflective areas together comprise at least 5%, generally 5 to 95%, of the total area of said other surface, said lens embossments having dimensions such that the plane or planes of the reflective areas are so positioned relative to the focal region or regions of one or more of the lenses that reflective areas together comprising at least 5% of said total area are in retro-reflective combination with one or more of said lenses.

The invention also provides a process for producing a plastics sheet material having preselected retro-reflective areas, which comprises forming a transparent or translucent layer of plastics material having one or more embossments on one surface thereof and printing or coating the other surface of said layer before during or after the embossing to provide reflective areas on said other surface and/or printing one or more surfaces of one or more further component layers of the sheet material to produce reflective areas thereon and bonding together the component layers of the sheet material, the printing or coating being of such extent that in the sheet material at least 5% of the total area of the surface shows reflective areas, the lens embossments having dimensions such that the plane or planes of the reflective areas are so positioned relative to the focal region or regions of one or more of the lenses that reflective areas together comprising at least 5% of the total area of said sheet material are in retro-reflective combination with one or more of said lenses.

One or more of the further component layers of said sheet be layers of opaque plastics material. If desired the embossing step and the lamination to one or more further component layers can be carried out simultaneously.

By "retro-reflective" we mean that a substantially parallel beam or ray of light incident on selected areas of the embossed surface of the sheet material is refracted and reflected in such a manner that most of the incident light is directed substantially back towards the source in a cone or wedge having a small apex angle even when the light strikes those selected areas at an angle. Although the apex angle of the cone or wedge is often larger it is ideally no more than 10°.

The reflective areas comprise at least 5%, generally from 5 to 95% of the planar area of the sheet and reflective areas together comprising at least 5% and preferably at least 10% of said total area in retro-reflective combination with one or more lenses. Preferably also, the reflective areas form all or part of a design or pattern. When only part, the remainder of the design may be printed, coated or laminated, substantially in the same plane or planes as the reflective areas or in planes above or below this plane, or these planes, providing the reflective areas to be in retro-reflective combination with lenses do not become masked from the light incident on the pre-selected areas of the sheet by the remainder of the design. If desired, part or all the remainder of the design may be printed, coated or laminated directly on to the embossed surface in which case a superposed transparent partial or overall protective layer of lacquer or plastics which may be tinted may be desirable; however in regions where the retro-reflective properties of the sheet are to be maintained the protective layer should be such that the retro-reffective properties are not substantially impaired.

The remainder of the design may comprise complete or open patterns in ink or coating materials, which may include transparent dyed lacquers, or may be in the form of a decorative film, foil, paper or fabric.

If desired, a transparent dyed lacquer may be printed or coated in regions such as to control the colour of the retro-reflective light.

It will be appreciated that the reflective areas may be produced by deliberately masking an overall reflective coating by an open design.

Suitable materials for printing or coating the reflective areas include hot blocking or stamping foils, gold, silver and aluminium lacquers, vacuum deposited aluminium and other metals, materials containing white pigments and/or fillers such as titanium dioxide and barium sulphate or any specular, semi-specular or diffusely reflecting substance. Luminescent materials may also be employed.

The embossed sheet may itself be tinted so as to provide an additional colour effect.

The transparent or translucent plastic materials suitable for use in the present invention include any thermoplastic or thermosetting plastics material which in its solid state is transparent or translucent and which preferably has a refractive index of at least 1.35. Thermoplastics are preferred in view of the ease with which these materials may be embossed by conventional sheet embossing machinery. Suitable thermoplastics include rigid and flexible p.v.c., polystyrene, polymethylmethacrylate, polyethylene, polyethylene terephthalate, polyethylene and polypropylene. Of these, flexible p.v.c. is most preferred since this material is not only easily embossed in a continuous manner but it may be sufficiently plasticised, with, for example, dioctyl phthalate and other well known plasticisers, to give products having the drape properties desirable for the sheet materials

of this invention when used in the manufacture of garments.

The layer of transparent or translucent plastics material having one or more convex lens embossments on one surface may be produced by any means including embossing one surface of a preformed sheet of the plastics material using a conventional embossing roller or die, extrusion casting the plastic material on to a suitably profiled casting surface, forming the plastic material directly in a suitably profiled casting die or extruding the plastic through a suitably profiled extrusion die. The technique employed will be governed to some extent by the nature of the plastic material also by the nature of the convex lens embossments desired. When the plastics material is flexible p.v.c. and the desired embossments do not comprise re-entrant sections a suitable technique is conventional thermal embossing of a preformed sheet using an embossing roller having one or more concave depressions in its surface.

It will be appreciated that the layer of transparent or translucent plastics material may comprise a single plastics material or a mixture of differing plastics materials. Where the sheet comprises more than one plastics layer the further component layers may each be of the same plastics material as the embossed layer or of plastics different to that of the embossed layer and may be different to one another and may each comprise a mixture of plastics.

The function of the lenses is to focus the incident light to their respective focal regions with consequent concentration of the light which may include an ultraviolet, infra-red or other component which may be deleterious to certain plastics materials. It may therefore be desirable to employ a layer or layers of plastics materials in the focal regions of the lenses which is/are resistant to any deleterious component of the incident light or to filter out such components before they reach the focal region.

In a preferred embodiment of the present invention each of the convex lens embossments comprises a segment of a sphere or of a cylinder and comprises no more than one half of the curved surface of the sphere or cylinder from which it is derived and preferably such that the base of the segment has an area equal to no more than 75% of the area of the base of a similar segment comprising a hemisphere or half-cylinder derived respectively from the same sphere or cylinder.

The convex lens embossments are preferably contiguous and where each comprises a segment of a sphere, they are preferably arranged in hexagonal close-packing array.

The curvature of each of the lens embossments is governed by the refractive indices of the materials employed and the permissible depth of the reflective areas of the design to be in retro-reflective combination with the lenses. The curvature is chosen such that a reflective area will lie in or near the focal region of at least one lens and such that the apex angle of the cone of retro-reflective light is small, ideally no more than 10°.

By focal region we mean, that region adjacent a lens in which there is a maximum concentration of light resulting from a parallel beam of light incident on the lens. When each of the convex lens embossments is derived from a sphere or cylinder as described in the preferred embodiment; due to aberration, a true focal point or line respectively cannot be defined. The elementary lens formula:—

$$f\left(\frac{r}{\mu-1}\right)$$

(where f=distance of focal point or line from the centre of curvature of the lens; r=radius of curvature of the lens and μ is the refractive index of the material of the lens with respect to the surrounding media) always over predicts the distance a reflective area should be from the centre of curvature of the lens with which it is in retro-reflective combination, for most applications for the sheet material of this invention. For a given radius of curvature of the lens each application dictates the relative position of the reflective area from the centre of curvature of the lens and may be arrived at by simple calculation using the above formula, followed by experiment.

The reflective areas need not necessarily all lie in the same plane providing each reflective area to be in retro-reflective combination is associated with the lens or group of lenses having a focal region or regions at or near the plane of the surface of that reflective area. The printing, coating or laminating of various components of the design in different planes may give rise to a three dimensional effect which is sometimes desirable. It will be appreciated that the individual layers of which the sheet material of this invention may comprise may be tinted or pigmented as desired providing the reflective areas are not masked from the light incident on the embossed surface of the sheet.

The overall design incorporating the reflective areas may comprise letters, figures or other indicia or a decorative pattern. When the sheet materials of this invention are intended for garment production, it is preferable for the design to be in the form of a textile pattern such as a tweed or drill pattern incorporating from 5 to 95% of re-

flective areas comprising pigments or other specular, semi-specular or diffusely reflecting matter so that in daylight the sheet material of the invention simulates the appearance of a fabric but is retro-reflective in pre-selected areas. In this way the safety of the wearer of an outer garment made from the sheet material of this invention is increased when on the highways during the hours of darkness. Safety garments made from the sheet material of this invention may thus be worn by children and other persons while avoiding the embarrassment of wearing brightly coloured clothing by day when this is not desirable. Alternatively, safety garments may be made which are partially fluorescent by day and also partially retro-reflective during the hours of darkness by employing fluorescent materials for the remainder of the design. Road signs and plaques partially fluorescent by day and partially retro-reflective at night can be made in a similar way.

The sheet materials of this invention may be laminated to various substrates to strengthen them or to take advantage of other desirable properties of the substrate. For example, a sheet material of this invention suitable for childrens garments may be reinforced by lamination to a textile fabric or a plastic sheet substrate to render it suitable for the manufacture of satchels and the like.

Where reference is made in this specification to sheet materials this term is intended to include sheets, films or tapes in discrete, semi-continuous or continuous lengths.

The following Examples will illustrate the sheet materials and processes of this invention.

Example 1

	Parts by weight
Bakelite (Registered Trade Mark) VY18 P.V.C. resin (B.X.L.)	100
Bisoflex 791 (Registered Trade Mark) (B.P. Chemicals U.K. Ltd)	40
Lankroflex (Registered Trade Mark) (Lankro Chemicals Ltd.) an epoxy-linseed oil plasticiser stabiliser)	3
Stabilizer Ferro (Registered Trade Mark) 9267 (Ferro Gt. Britain) Ltd.) (a barium/cadmium-zinc stabiliser)	2.5

A clear, flexible p.v.c. sheet of the above refractive index 1.52 was embossed with a hexagonally close-packed pattern of convex lenses in the following manner.

The p.v.c. sheet was pre-heated to approximately 130° by passing it over heated rollers, the surface to be embossed was then flash heated by passing it under an Elstein infra red heater of dimensions 4.5in × 2.5in running at 5 kilowatts per square foot, at a speed of 6 feet/min. and at a distance of 0.5 inch from the heater. The sheet was then immediately passed through an embossing nip comprising a water-cooled metal embossing roller and a rubber back-up roller. The embossing roller used was engraved with hexagonally close-packed depressions having the shape of segments of a sphere of radius of curvature 0.007 inch and of depth such that the diameter of the base of an isolated lens on the surface of the embossed p.v.c. sheet was 0.0054 inch.

The thus embossed p.v.c. sheet was then cut into panels each of which was printed on the unembossed surface by an off-set lithographic process, with a tweed pattern containing approximately 10% by area of highly reflective silver colour. The remainder of the tweed pattern comprised two other colours, brown and black. The printing ink used for the highly reflective silvered areas was Ready-mix Silver Ink No. 17 manufactured by Johnson and Bloy Ltd., which we believe to be based on an aluminium paste. The tweed pattern was printed by first applying the highly reflective ink to selected areas, drying, and then printing the further two colours sequentially drying between each colour.

The final product had a superficial tweed-like appearance by day and at night, when viewed in an artificial light beam at a distance of 200ft, could be seen at least as easily as a wooden panel of equal area and coated overall with gloss white paint.

Example 2

A P.V.C. sheet of the formulation given in Example 1, 0.022 inch thick, was laminated in a conventional laminating press to the surface of a layer of .010 inch p.v.c. of the same formulation on which an abstract pattern containing about 12% by area of silver colour had been printed using Ready-mix Silver Ink No. 17 as in Example 1, and lenses were then embossed on the outer surface of the thicker material as in Example 1.

A panel cut from the resulting laminate had a pleasing appearance by day and when viewed in an artificial light beam at night and at a distance of 200ft was at least as visible as a wooden panel of equal area and coated overall with gloss white paint.

Example 3

A p.v.c. sheet as in Example 1 was printed on one surface with silver coloured reflective areas comprising 12% by area of that surface using Ready-mix Silver Ink No.

17. The thus printed sheet was then laminated in a conventional laminating press to a .010 inch p.v.c. sheet of the same formulation on which an abstract design had been printed, the printed faces being brought into contact during lamination. The laminate thus produced was then embossed as in Example 1 and lenses formed on the unprinted surface of the thicker component of the laminate.

A panel cut from the resulting product when viewed at night in an artificial light beam at a distance of 200 ft, was at least as visible as a wooden panel of equal area and coated overall with gloss white paint.

Example 4

An embossed panel produced as in Example 1 was printed on its smooth surface using Ready-mix Silver Ink No. 17, with circular areas of aproximate diameter of .006 inch and which together comprised 15% of the total area of the surface. A layer of fluorescent lacquer was then applied over the entire surface including the silvered areas.

The resulting product had a fluorescent appearance by day and exhibited retro-reflective areas at night when viewed in an artificial light beam.

Example 5

A clear p.v.c. sheet (A) produced to the formulation given in Example 1 and of thickness 0.008 inch and a similar sheet (B) pre-printed with an overall abstract design containing approximately 45% of reflective areas printed using Gravure Silver PDM 14347 Ink (produced by Colora Ink Company of Harlow), the remainder of the pattern being printed using Gravure Red G.V. 29919 Ink, (produced by Coates Bros. Inks. Ltd, of St. Mary Cray), were laminated and embossed in the following manner: the two sheets (A) and (B) were fed together into an embossing-laminating machine such that the printed surface of sheet (B) was in contact with one surface of sheet (A) and the combination pre-heated to approximately 150°C by bringing each side sequentially into contact with metal rollers each of diameter 18 inches maintained at approximately 160°C and running at a peripheral speed of 20 feet/min. The outer surface of sheet (A) was then flash-heated by passing the combination vertically downwards with the surface of sheet (A) facing towards an infra-red heater space at a distance of 8 inches comprising a bank of radiant elements arranged to give a heater rating of 1 kw/50 square inches. The combination was then passed vertically downwards into an embossing nip comprising a water-cooled embossing roller, as described in Example 1, of diameter 5 inches and a rubber backup roller of diameter 5 inches with the surface of sheet (A) in contact with the embossing roller, such that lamination of sheet (A) and sheet (B) was effected with simultaneous embossing of the surface of sheet (A) with hexagonal close-packed lenses.

A panel cut from the product exhibited an attractive, colourful abstract pattern by day and, at night when viewed in an artificial light beam at a distance of 200 ft, could be seen at least as easily as a wooden panel of equal area and coated with gloss white paint.

Example 6

Example 5 was reepated except that sheet (B) of thickness 0.008 inch was produced from the following opaque formulation and was pre-printed only with the Gravure Silver Ink, the remainder of the printing being omitted:—

Breon (Registered Trade Mark) 125/10 p.v.c. (British Geon Ltd.)	100
Bisoflex 791 (B.P. Chemicals U.K. Ltd.)	48
White lead paste	3
Lead stearate	½
Carbon black	1

A panel cut from the product exhibited an attractive abstract pattern by day and, at night, when viewed in an artificial light beam at a distance of 200 ft, could be seen at least as easily as a wooden panel of equal area and coated with gloss white paint.

WHAT WE CLAIM IS:—

1. A plastics sheet material having pre-selected retro-reflective areas, which sheet comprises one or more layers of transparent or translucent plastics material, one layer, comprising the surfacce of said sheet, having one or more convex lens embossments on one surface thereof, said embossments having dimensions such that the plane or planes of reflective areas printed or coated on the other surface of the said one layer and/or on one or more surfaces of any further component layers of said sheet which reflective areas together comprise at least 5% of the total area of said other surface, are so positioned relative to the focal region or regions of one or more of the lenses that reflective areas together comprising at least 5% of said total area are in retro-reflective combination with one or more of said lenses, the other surface of such layer and the surfaces of any other component layer being substantially smooth and unembossed.

2. A plastics sheet material as claimed in claim 1, wherein one or more further com-

ponent layers are layers of opaque plastics material.

3. A plastics sheet material as claimed in claim 1 or claim 2, wherein the reflective areas comprise from 5 to 95% of the total area of said other surface.

4. A plastics sheet material as claimed in any one of claims 1 to 3, wherein the plastics material is a thermoplastics material.

5. A plastics sheet material as claimed in claim 4, wherein the thermoplastics material is flexible polyvinyl chloride.

6. A plastics sheet material as claimed in in any one of claims 1 to 5, wherein each embossment comprises a segment of a sphere or of a cylinder, said segment being not more than a half-segment.

7. A plastics sheet material as claimed in claim 6, wherein the base area of the segment is not more than 75% of the area of a half-segment.

8. A plastics sheet material as claimed in any one of claims 1 to 7, wherein each embodiment is a segment of a sphere and the embossments are in a hexagonal close-packed arrangement.

9. A plastics sheet material as claimed in any one of claims 1 to 8, which is in the form of a garment material.

10. A plastics sheet material as claimed in claim 1, substantially as described in any of the Examples herein.

11. A garment made from a plastics sheet material as claimed in claim 9.

12. A process for producing a plastics sheet material as claimed in any one of claims 1 to 9, which comprises forming a transparent or translucent layer of plastics material having one or more convex lens embossments on one surface of said layer and printing or coating the other surface of said layer before, during or after the embossing to provide reflective areas on said other surface, which reflective areas together comprise at least 5% of the total area of said other surface, the lens embossments having dimensions such that the plane or planes of the reflective areas are so positioned relative to the focal region or regions of one or more of the lenses that reflective areas together comprising at least 5% of said total area are in retro-reflective combination with one or more of said lenses.

13. A process for producing a plastics sheet material as claimed in any one of claims 1 to 9, which comprises forming a transparent or translucent layer of plastics material having one or more lens embossments on one surface thereof and printing or coating the other surface of said layer before, during or after the embossing to provide reflective areas on said other surface and/or printing or coating one or more surfaces of one or more further component layers of the sheet material to produce reflective areas thereon and bonding together the component layers of the sheet material, the printing or coating being of such extent that in the sheet material at least 5% of the total area of the surface shows reflective areas, the lens-embossments having dimensions such that the plane or planes of the reflective areas are so positioned relative to the focal region or regions of one or more of the lenses, that reflective areas together comprising at least 5% of the total area of said sheet material are in retro-reflective combination with one or more of said lenses.

14. A process as claimed in claim 13, wherein the embossing and the bonding together of the component layer is carried out simultaneously.

15. A process as claimed in claim 13 or claim 14, wherein the component layers are bonded together by thermal fusion.

16. A process as claimed in claim 12, substantially as described in either of Examples 1 and 4 herein.

17. A process as claimed in claim 13, substantially as described in any one of Examples 2, 3, 5 and 6.

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